IMPACT OF BMP'S ON STREAM AND GROUND WATER QUALITY IN A USDA DEMONSTRATION WATERSHED IN THE EASTERN COASTAL PLAIN

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ABSTRACT

A USDA Water Quality Demonstration project in the Herrings Marsh Run (HMR) watershed in Duplin County, North Carolina was initiated in 1990. The HMR watershed is representative of an eastern Coastal Plain watershed with intensive agricultural practices (*e.g.*, crop, swine, poultry, and cattle production). Stream sampling stations were established at four locations in the watershed to evaluate the influences of agricultural practices on stream water quality. Ninety-two monitoring wells were installed on 21 farms throughout the watershed to evaluate the influences of agricultural practices on ground water quality. Stream water at a HMR tributary was consistently of lower quality than water from the HMR main channel. Nitrate-nitrogen and ortho-phosphate levels consistently exceeded 5 and 1 mg/L, respectively, in stream water at the HMR tributary. Mean nitrate-nitrogen in ground water at five farms exceeded 10 mg/L, possibly caused by animal waste water application and/or excessive use of commercial fertilizers. Both triazines and chloroacentanilides were detected in approximately 20% of the monitoring wells during some sampling months. The majority of these pesticide detects had concentrations well below the maximum contaminant level for safe drinking water. These data indicate that current and past agricultural management practices have degraded water quality in both stream and ground waters.

INTRODUCTION

Even though significant progress has been made in the development and implementation of agricultural best management practices (BMP's), nonpoint pollution of surface and ground water by agriculture is a major water quality concern (Bjerke, 1989; Bouwer, 1987; Hurlburt, 1988; Hubbard et al, 1986; and Hubbard and Sheridan, 1989). A five-year water quality demonstration project involving federal, state, and local agencies, private industry, and local land owners was initiated in 1990 on a watershed located on the Cape Fear River Basin in Duplin County, North Carolina. The 2044 ha demonstration watershed, Herrings Marsh Run (HMR), is one of the eight original demonstration projects funded as part of the USDA's Presidential Water Quality Initiative, and it is located within the Goshen Swamp Hydrologic Unit Area one of the 37 original hydrologic unit area projects (United States Department of Agriculture and Cooperating State Agencies, 1989). Duplin County has many of the characteristics of an intensive agricultural county in the eastern Coastal Plain of the USA. Duplin County, NC, has the highest agricultural revenue of any county in North Carolina. In 1990, it had the highest population of turkeys and the fourth highest population of swine of any county in the United States (North Carolina Dept. of Agriculture, 1990).

Agricultural management practices on the watershed are typical for the southeastern Coastal Plain and include 1093 ha of cropland, 708 ha of woodlands, and 212 ha of farmsteads, poultry facilities, and swine facilities. The major agricultural crops on the watershed include tobacco (131 ha), corn (415 ha), soybeans (273 ha), wheat (121 ha), and vegetables (162 ha). The predominant soil series in the watershed is Autryville (Loamy, siliceous, thermic Arenic Paleudults); secondary soil series are Norfolk (Fine-loamy, siliceous, thermic Typic

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Kandiudults), Marvyn-Gritney (Clayey, mixed, thermic Typic Hapludults), and Blanton (Loamy siliceous, thermic Grossarenic Paleudults).

Current annual nutrient usage for crop production on the watershed is estimated at 145 metric tons of nitrogen, 64 metric tons of phosphorus, and 243 metric tons of potassium. Although swine and poultry operations produce sufficient quantities of waste to supply over half of the needed nutrients, 90% of the nutrients applied to cropland are supplied by commercial fertilizers. The application of large quantities of commercial fertilizers coupled with the production of large quantities of animal waste provides a potential for nitrogen and phosphorus contamination of surface and ground water. The objective of the initial phase of the project has been to evaluate the effect of current agricultural management practices on stream and ground water quality within the watershed.

METHODS

Surface water sampling stations were established in August 1990, at three locations within the watershed (Fig. 1). Station 1, Red Hill, was located at the stream outlet from the watershed. Station 2, Herrings Marsh Run Tributary, was located along a tributary downstream from intensive swine and poultry operations. Station 3, Herrings Marsh Run Main, was located along the main stream run flowing through woodlands. The woodlands located above Station 3 has a substantial riparian buffer compared with the riparian buffers for Station 2. Station 3 was chosen to represent background conditions due to the large riparian buffer and because no animal production facilities were in the subwatershed. Station 4, Red Hill tributary, was installed in August 1991, to provide additional information about the eastern portion of the watershed. The U. S. Geological Survey in Raleigh, NC, installed gaging stations at the initial three stations in April 1991. A gaging station was installed at Station 4 in August 1991. Isco 2700 automated water samplers were installed at each station. Sample collection was continual from October 1990 to the present time. The water samplers combine hourly samples into a daily composite. The samples were collected weekly and transported to the laboratory for analysis. The gaging stations measure flow at 15-min intervals using automated water level recorders.

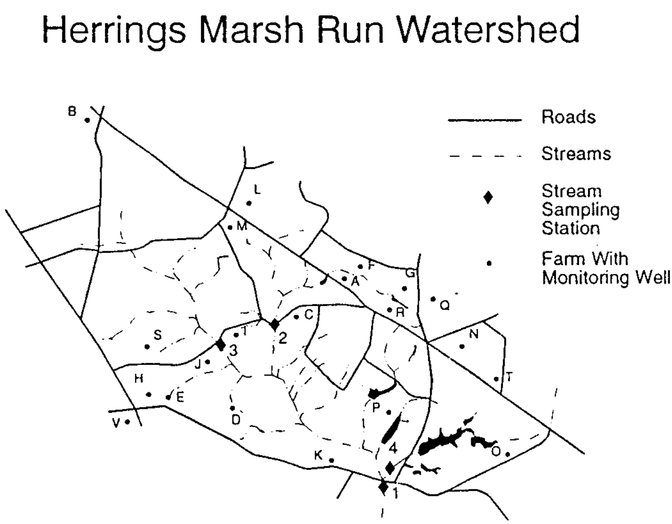

Figure 1. Location of stream gaging stations and farms with ground water monitoring wells on Herrings Marsh Run watershed.

Ground water monitoring wells were established on 21 farms in the HMR watershed (Fig. 1) beginning in August 1991 and continuing through March 1993. These farms exemplify the agricultural practices used in the watershed. The farms were selected to cover the watershed both on a geographical basis and to represent the farming practices on the watershed. The majority of, the farms with monitoring wells are in row crops with and without implemented nutrient management plans. Two of the row crop farms have their main source of nitrogen from poultry litter and poultry compost. The other farms have practices which include the application of swine lagoon effluent to pasture (Farm A) and a farm with pasture for hay production. Monitoring wells at Farm F are located around a poultry compost facility.

Ground water monitoring wells were installed using a SIMCO 2800** trailer-mounted drill rig equipped with 108-mm inside diameter hollow stem augers. The well casings and screen were 50-mm threaded schedule 40 PVC, and well screens were 1.5 m long. Well bottoms were placed on an impermeable layer or to a depth of 7.6 m if the impermeable layer could not be located above that depth. Water table depths in the watershed were generally 1.5 to 3 m below the soil surface. Monitoring wells were constructed according to N. C. Dept. of Environmental Management regulations. A filter pack of coarse sand was placed around well screens. An annular seal of bentonite was placed above the filter sand. Concrete grout was then placed above the bentonite to the soil surface to prevent contamination from the surface. Locking well covers were installed to prevent unauthorized access. WaTerra foot valves (model D-25) and high density polyethylene tubing were installed in each well to provide dedicated samplers.

At Farm A, ground water sampling transects were established in the swine lagoon effluent application field. Both transects had wells in the spray field (in-field), at the edge of the field (field-edge), and at the edge of a stream (stream-edge) that flows through the farm. Wells were placed at two depths, 4.6 and 7.6 m in each location, and one well was placed at 15 m. The 4.6- and 7.6-m sampling depths were immediately below and approximately 3 m below the water table, respectively. The area between the field-edge and stream-edge contained a small riparian buffer. Stream grab samples were taken adjacent to the stream-edge samples for two of the transects. At the other farms monitoring wells were placed around fields to a depth of 7.6 m. These wells were located both up and down slope of the various practices to monitor ground water flowing from the fields.

Before samples were collected, the static well water depths were measured, and three well volumes were purged. Glass sample collection bottles were rinsed with the well water before sample collection, filled with sample, packed in ice, and transported to the laboratory. Wells were sampled monthly.

All water samples were transported to the USDA-ARS, Soil, Water, and Plant Research Center in Florence, SC, for analysis. Water samples were analyzed using a TRAACS 800 Auto-Analyzer for nitrate-nitrogen, ammonium-nitrogen, total Kjeldahl nitrogen, ortho-phosphorus, and total phosphorus using EPA Methods 353.2, 350.1, 351.2, 365.1, and 365.4, respectively (U.S. EPA, 1983). EPA-certified quality control samples were routinely analyzed to verify results. Ground water samples were initially screened for triazines and chloroacentanilides using immunoassay techniques and detects were confirmed by gas chromatography/mass spectroscopy (GC/MS). All statistical analysis of the data was accomplished using SAS version 6.07 (SAS, 1990).

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RESULTS AND DISCUSSION

Mean daily nitrate-nitrogen concentrations (Table 1) of water leaving the watershed outlet, Red Hill (Station 1), and at HMR tributary (Station 2) were two and four times higher, respectively, than background concentrations as represented by HMR main (Station 3). Daily mean nitrate-nitrogen concentrations at the HMR tributary periodically exceeded 10 mg/L. Overapplication of swine lagoon effluent and undersized, overloaded lagoons are likely contributors to the elevated nitrate-nitrogen concentrations in the HMR tributary.

Mean daily ammonium-nitrogen concentrations of water at the watershed outlet and at the HMR tributary were two and seventeen times higher, respectively, than background concentrations (Table 1). Ammonium-nitrogen concentrations at the watershed outlet and at HMR tributary exceeded limits considered harmful to humans (0.5 mg/L) and fish (2.5 mg/L) (U.S. EPA, 1973). During the first month of the sampling period, daily ammonium-nitrogen concentrations at HMR tributary ranged from 6 to 12 mg/L. These high concentrations of ammonium-nitrogen indicate that a significant discharge of animal waste products into the waterway had occurred. After the first month, daily mean ammonium-nitrogen concentrations did not exceed 4 mg/L.

Table 1. Mean daily nutrient concentrations and mass fluxes over the sampline period for four stream monitoring stations in the Herrings Marsh Run watershed in Duplin County, NC.

	Stations*			
	1	2	3	4
Concentration	mg/L			
NO_3-N	2.01	5.34	1.18	1.26
PO_4-P	0.14	0.54	0.06	0.07
NH_4-N	0.15	0.42	0.08	0.18
Mass Flux	kg/day			
NO_3-N	22.17	19.61	3.56	2.18
PO_4-P	2.24	2.04	0.17	0.13
NH_4-N	2.08	1.34	0.28	0.37
	m^3/s			
Stream Flow	0.147	0.041	0.034	0.025

* Station 1 is located at the watershed outlet. Station 2 is the Herrings Marsh Run tributary. Station 3 is the Herrings Marsh Run main and is used as a background reference. Station 4 is the Red Hill tributary.

Mean daily ortho-phosphorus concentrations of water at the watershed outlet and at HMR tributary were five and ten times higher, respectively, than background concentrations (Table 1). On ten daily occurrences, ortho-phosphorus concentrations of water at the exit of the watershed were significantly higher than at HMR tributary. The origin of these peaks is unclear.

Stream flow data from the USGS Gaging stations (USGS, 1992) began in April 1991 for three stations (Red Hill, HMR tributary, and HMR main) and in August 1991 for the fourth station (Red Hill tributary). The stream flow data were integrated with the stream monitoring data to calculate the mass loading of nitrate-nitrogen and ammonium-nitrogen. The mass nitrate-nitrogen leaving the watershed (Red Hill) averages approximately 30 kg/day. The HMR tributary monitoring station has approximately 22 kg/day leaving that sub-watershed. The mass ammonium-nitrogen at Red Hill and HMR tributary frequently exceed 5 and 3.5 kg/day, respectively. Ortho-phosphorus mass flux at the watershed outlet averages 7 kg/day while the HMR tributary and HMR Main averages 3.5 and 0.7 kg/day, respectively.

Mean of monthly ground water nitrate-nitrogen and ammonium-nitrogen concentrations for the monitored farms are presented in Table 2. Both nitrate-nitrogen and ammonium-nitrogen concentrations in ground waters at Farm A consistently exceeded 10 mg/L. In addition, the mean nitrate-nitrogen and ammonium-nitrogen concentrations in stream water at Farm A were 8 and 4 mg/L, respectively. At Farm A, the elevated nitrate-nitrogen concentrations was believed to be directly related to the land application of swine wastewater that has been an on-going operation since 1986. The spray field for the waste application was undersized due to expansion of the swine operation since its original design. Prior to 1991, the spray field had no permanent grass cover; row crop or weed fallow served as the ground cover. Additionally, it was suspected that the overloading may be degrading the performance and efficiency of nutrient removal in the lagoon.

Table 2. Mean of monthly nitrate-N and ammonium-N concentrations in ground water monitoring wells located within the demonstration watershed.

Farm	Nitrate-N		Ammonium-N	
	(mg/L)	Std. Dev.	(mg/L)	Std. Dev.
A	72.7	64.9	16.5	16.2
B	10.9	6.4	0.25	0.3
C	16.8	4.13	0.27	0.28
D	5.62	5.49	0.29	0.42
E	6.48	1.24	0.28	0.34
F	11.1	8.71	0.44	0.97
G	7.67	2.1	0.2	0.41
H	10.3	8.55	0.36	0.52
I	8.23	1.4	0.24	0.39
J	0.73	1.92	0.18	0.22
K	1.65	1.33	0.18	0.23
L	4.28	6.39	0.26	0.71
M	8.18	7.15	0.26	0.24
N	1.49	1.9	0.25	0.2
O	7.41	4.1	0.2	0.28
P	7.7	6.44	0.23	0.16
Q	7.96	7.48	0.24	0.33
R	17.1	24.8	0.23	0.26
S	6.02	1.91	0.19	0.11
T	5.11	2.12	0.15	0.16
U	2.23	2.35	0.22	0.07
V	2.47	0.16	0.17	0.07

Elevated nitrate-nitrogen concentrations at Farm F are possibly due to pre-existing contamination from contiguous poultry houses. The elevated nitrate-nitrogen concentrations at other farms in the watershed are likely related to nonpoint sources of nitrogen due to overapplication of fertilizer. It appears that improved nutrient management will be helpful on these farms. The majority of other farms appear to have appropriate nutrient management budgets since the nitrate-nitrogen concentrations were less than 10 mg/L.

Over a 10-month period, immunoassay analyses of ground water showed that triazines and chloroacentanilides were detected in less than 20% of the 92 monitoring wells. Detects in monitoring wells varied monthly. Both atrazine and alachlor were confirmed (with GC/MS) in a number of ground water samples. The majority of detected concentrations were well below the maximum contaminate level for safe drinking water.

SUMMARY

Results from the initial phase of the five-year project indicate that most of the streams and ground waters of the watershed have acceptable water quality. The stream water at the watershed outlet and station 2 had elevated nitrate-nitrogen and ammonium-nitrogen concentrations. The elevated concentration levels at station 2 are believed to be directly related to the high concentration of swine production facilities in that subwatershed along with the reduced riparian buffers. The mass flux from this subwatershed accounts for over two-thirds of the nitrate-nitrogen leaving the watershed at the watershed outlet.

Ground water on the farms sampled in the watershed has indicated that over eighty percent have nitrate-nitrogen concentrations below 10 mg/L. Four farms had elevated nitrate-nitrogen concentrations between 10 and 20 mg/L. Only one farm had nitrate-nitrogen concentrations in ground water that exceeded 20 mg/L. Triazines and chloroacentanilides were periodically detected in some wells but the majority of the concentrations were below safe drinking water standards. It appears that traditional agricultural management practices on the watershed have had an adverse impact on the quality of surface and ground water at specific locations.

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